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Condylar resorption in orthognathic patients after mandibular bilateral sagittal split osteotomy: a systematic review

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Abstract: OBJECTIVE: To systematically search the literature and assess the available evidence regarding the incidence and quantification of condylar resorption following bilateral sagittal split osteotomy (BSSO) of the mandible in orthognathic patients. SEARCH METHODS: Electronic database searches of published and unpublished literature were performed. The reference lists of eligible studies were hand searched for additional studies. SELECTION CRITERIA: Randomized clinical trials (RCTs), prospective, and retrospective studies with patients of any age that underwent BSSO were included. DATA COLLECTION AND ANALYSIS: Study selection, data extraction, and risk of bias assessment were performed individually and in duplicate. RESULTS: One RCT, 3 prospective, and 10 retrospective studies were included in this review. The lack of standardized protocols and the high amount of heterogeneity precluded a valid interpretation of the actual results through pooled estimates. There was a substantial consistency among studies, however, that young, female patients with mandibular deficiency and high mandibular plane angle, submitted to surgical counterclockwise rotation of mandibular segments, were more prone to a higher risk for condylar resorption after BSSO. The level of evidence was found to be low given the high/serious risk of bias in all included studies. CONCLUSIONS: Condylar resorption should be taken into account as a potential postsurgical complication after BSSO. However, its incidence and quantification need precautious interpretation owing to the low level of evidence and the high heterogeneity of studies. Additional high-quality prospective research assisted by 3D imaging technology is needed to allow more definitive conclusions. REGISTRATION: Study not registered. CONFLICT OF INTEREST: None.

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Article Title : “CONDYLAR RESORPTION IN ORTHOGNATHIC PATIENTS AFTER MANDIBULAR BILATERAL SAGITTAL SPLIT OSTEOTOMY. A SYSTEMATIC REVIEW.”

Short running title: “Condylar resorption after BSSO”

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ABSTRACT

Objective: To systematically search the literature and assess the available evidence regarding the incidence and quantification of condylar resorption following bilateral sagittal split osteotomy (BSSO) of the mandible in orthognathic patients.

Search methods: Electronic database searches of published and unpublished literature were performed. The reference lists of eligible studies were hand searched for additional studies.

Selection criteria: Randomized clinical trials (RCTs), prospective and retrospective studies with patients of any age that underwent BSSO were included.

Data collection and analysis: Study selection, data extraction and risk of bias assessment were performed individually and in duplicate.

Results: One RCT, 3 prospective and 10 retrospective studies were included in this review. The lack of standardized protocols and the high amount of heterogeneity precluded a valid interpretation of the actual results through pooled estimates. There was a substantial consistency among studies, however, that young, female patients with mandibular deficiency and high mandibular plane angle, submitted to surgical counterclockwise rotation of mandibular segments were more prone to a higher risk for condylar resorption after BSSO. The level of evidence was found to be low given the high/serious risk of bias in all included studies.

Conclusions: Condylar resorption should be taken into account as a potential postsurgical complication after BSSO. However, its incidence and quantification need precautious interpretation owing to the low level of evidence and the high heterogeneity of studies. Additional high quality prospective research assisted by 3-D imaging technology is needed to allow more definitive conclusions.

Registration: Study not registered.

Conflict of interest: None.

INTRODUCTION

Bilateral sagittal split osteotomy (BSSO) is an established and well-documented surgical procedure for the correction of mandibular deformities, including mandibular deficiency, excess and/or asymmetry (1). It is commonly considered as the surgical technique of election for the treatment of skeletal Class II cases with mandibular hypoplasia (2).

Postoperative alterations following BSSO for mandibular advancement, such as increased loading of the temporomandibular joint (TMJ) or positional condylar changes may occur (3). The extent at which these changes exceed the natural adaptive capacity of the TMJs is likely to give rise to clinical entities, known as condylar remodeling and resorption (4). Condylar remodeling is a physiologic adaptive mechanism of the TMJs to meet the functional demands (5). On the other hand, condylar resorption (CR) is defined as a progressive change in condylar configuration followed by a decrease in mass (6-8). It is also often met in literature under the following terms: condylysis, osteoarthrosis, dysfunctional remodeling, avascular necrosis, osteonecrosis and condylar atrophy (9).

CR is reported as a late postoperative relapse (>12 months) after BSSO for mandibular advancement (4) leading to decreased posterior facial height, clockwise mandibular rotation, mandibular retrognathism and anterior open bite (10, 11). The first to report on the incidence of bilateral condylar atrophy after BSSO were Philips and Bell in 1978 (10, 12). They assumed that atrophy occurred as a result of resorption due to increased muscle tension of the geniohyoid and the anterior digastric muscles (12).

CR following BSSO is affected by several factors that can be related either to patient's characteristics or the surgical procedure itself. Contributing patient-related factors are the female gender, young age ranging from 15 to 35 years, mandibular hypoplasia with high mandibular plane angle (MPA), preoperative TMJ dysfunction (TMD) and posterior inclination of the condylar neck (2, 7, 10, 11, 13-15). Surgery-related factors include large mandibular advancement, counterclockwise rotation of the proximal segments and type of fixation (2, 3, 7, 11, 16).

Although the occurrence of CR following orthognathic surgery has been reported to vary from 1% to 31% (9) depending on the aforementioned factors, the incidence of CR after BSSO without any other simultaneously performed surgical procedures, such as LeFort I osteotomy, genioplasty, etc., as well as the subsequent amount of bone loss have been analyzed less thoroughly. Therefore, the aim of the present systematic review was to assess the available scientific evidence regarding the incidence and quantification of CR following BSSO of the mandible in orthognathic patients.

MATERIALS AND METHODS

This systematic review (SR) was based on the guidelines of the PRISMA Statement for reporting SRs and MAs of studies evaluating health-care interventions (17).

2.1 Protocol and registration

Not available.

2.2 Selection criteria

- Study design: Any study design was considered eligible for inclusion in this review, including randomized clinical trials (RCTs), non-randomised or quasi-randomised controlled trials, prospective and retrospective studies.
- Types of participants: Patients of any age that underwent a Bilateral Sagittal Split Osteotomy (BSSO) for shifting of the mandible.
- Type of intervention: BSSO alone, or in conjunction with other surgical procedures.
- Outcome: Condylar resorption.
- Follow-up: All observation periods were accepted.
- Exclusion criteria: Animal and *in-vitro* studies. Case reports or studies reporting outcomes from less than 10 patients.

2.3 Search strategy for identification of studies

Detailed search strategies were developed and appropriately revised for each database, considering the differences in controlled vocabulary and syntax rules. The following electronic databases were searched: MEDLINE (via Ovid and PubMed, Appendix 1, from 1946 to November 29th, 2015), EMBASE (via Ovid), the Cochrane Oral Health Group's Trials Register and CENTRAL.

Unpublished literature was searched on ClinicalTrials.gov, the National Research Register, and Pro-Quest Dissertation Abstracts and Thesis database. The search attempted to identify all relevant studies irrespective of language. The reference lists of all eligible studies were hand-searched for additional studies.

2.4 Selection of studies

Two review authors (SM, DK) performed the study selection independently and in duplicate. They were not blinded to the identity of the authors or their reported results. Selection of the eligible studies was based on screening of the titles, abstracts and full-text. Any disagreement was resolved by consulting a third reviewer (TV). Reviewers kept a record of all the decisions on study identification.

2.5 Data extraction and management

Two authors (SM, DS) made the assessment of the articles individually and in duplicate in predefined data extraction forms. No blinding to the authors during data extraction was made and any inter-examiner conflicts were resolved by discussion or the involvement of two collaborators (DK, TE). In order to record the desire information, the following customized data collection forms were used:

- Author/title/year of publication
- Setting/design/year of study
- Number/age/gender of patients recruited
- Skeletal type of patients
- Exact surgical procedure, type of jaws' fixation
- Observation period (follow up of patients)
- Method and timing of outcome assessment
- Assessment of confounders
- Definition of outcome
- Events and amount of resorption

2.6 Measures of treatment effect

For continuous outcomes, mean differences and standard deviations were planned to be used to summarise the data from each study. For dichotomous data, number of condylar resorption events and total number of patients in experimental and control groups were planned to be analysed. Regarding meta-analysis for dichotomous data risk ratios (RR) and their 95% confidence intervals (Cls), while for continuous data mean difference (MD) and 95% Cls would have been calculated.

2.7 Unit of analysis issues

In all cases, the unit of analysis was the patient.

2.8 Dealing with missing data

We tried to contact study authors via email to request information where missing. In case of no response or no access of the missing data, only the available data were reported and analyzed.

2.9 Assessment of heterogeneity

We planned to assess clinical heterogeneity by examining the characteristics of the studies, the similarity between the types of participants, the interventions and the outcomes as specified in inclusion criteria. Statistical heterogeneity would have been assessed using a Chi^2 test and the I^2 statistic, where I^2 values over 50% would indicate substantial heterogeneity.

2.10 Assessment of reporting bias

Reporting biases arise when the reporting of research findings is affected by the nature or direction of the findings themselves. We attempted to minimise potential reporting biases including publication bias, multiple (duplicate reports) publication bias and language bias in this review, by conducting an accurate and at the same time a sensitive search of multiple sources with no restriction on language. We also searched for ongoing trials. In the presence of more than 10 studies in a meta-analysis, the possible presence of publication bias would have been investigated constructing a funnel plot (18) and investigating any asymmetry detected.

2.11 Data synthesis

We planned to conduct meta-analyses if there were studies of similar comparisons reporting the same outcomes at the same follow-up periods. Risk ratios would have been combined for dichotomous data using fixed-effect models, unless there were more than three studies in the meta-analysis, when random-effects models would have been used.

2.12 Quality assessment

The methodological quality of the retrieved studies was performed independently and in duplicate by two reviewers (SM, DS). Again, any inter-examiner conflicts were resolved by discussion or the involvement of two collaborators (DK, TE).

The risk of bias of RCTs was assessed, using the Cochrane risk of bias tool (19). Seven domains of bias were estimated: sequence generation, allocation concealment, blinding of participants and investigators, blinding of outcome assessors, incomplete outcome data, selective outcome reporting and other sources of bias. A judgment of low, high or unclear risk of bias was made for each of the seven domains, while a final overall judgment was assessed based on the following:

- Low risk of bias (plausible bias unlikely to seriously alter the results) if all key domains of the study were at low risk of bias.
- Unclear risk of bias (plausible bias that raises some doubt about the results) if one or more key domains of the study were unclear.
- High risk of bias (plausible bias that seriously weakens confidence in the results) if one or more key domains were at high risk of bias.

Prospective and retrospective studies were evaluated with ACROBAT-NRSI (A Cochrane Risk of Bias Assessment Tool for Non-Randomized Studies of Interventions) (20). Seven domains of bias were also estimated: bias due to confounding, bias in selection of participants, bias in measurement of interventions, bias due to departures from intended interventions, bias due to missing data, bias in measurement of outcomes, bias in selection of the reported result. A low, moderate, serious, critical risk of bias or no information on which to base a judgment on risk of bias were the response options for each domain. Finally, an overall risk of bias for each study was reached based on the following:

- Low risk of bias (the study is comparable to a well-performed RCT) if low risk of bias applied for all domains.
- Moderate risk of bias (the study appears to provide sound evidence for a non-randomized study but cannot be considered comparable to a well-performed RCT) if low or moderate risk of bias applied for all domains.
- Serious risk of bias (the study has some important problems) if the study was judged to be at serious risk of bias in at least one domain, but not at critical risk in any other.
- Critical risk of bias (the study is too problematic to provide any useful evidence on the effects of intervention) if the study was at critical risk in at least one domain.
- No information (on which to base a judgment on risk of bias) if there was no clear indication that the study was at serious or critical risk *and* there was lack of information in one or more key domains of bias.

Moreover, important confounders and con-interventions were considered all those factors and interventions, respectively, that could have an impact on the reported incidence of CR according to the literature (2, 9-11, 15). Thus, the following confounders were taken into account both for patients and controls: female gender, young age (15 to 35 years), preoperative temporomandibular joint dysfunction (TMD), mandibular hypoplasia with high mandibular plane angle (MPA) and posterior inclination of condylar neck. Moreover, co-interventions were considered those that were not part of the intended intervention, in our case the BSSO. Therefore, bimaxillary surgery and intermaxillary fixation (IMF) after BSSO were taken into consideration.

RESULTS

3.1 Study selection

The electronic search initially identified 495 relevant articles. 175 papers remained after the duplicates' removal and after exclusion on the basis of title-reading. Three articles were added through hand-searching. After abstract-reading, 158 studies were excluded, and therefore 20 articles remained to be read in full-text. After the application of the specific inclusion and exclusion criteria another 6 articles were removed. Two studies had to be translated from Chinese and Dutch. The former was finally included in the review, whereas the latter was excluded. In total, 14 studies were considered eligible for inclusion in the final analysis (Figure 1).

3.2 Study characteristics

The characteristics of each study are presented in detail in Table 1. Only 1 study (21) was RCT, 3 studies were of prospective (4, 22, 23) and 10 of retrospective design (15, 24-32).

The flow diagram of the retrieved studies is presented in Figure 1.

3.3 Quality analysis

The risk of bias analysis of the 14 studies is shown in Table 2.

RCT study

The only RCT (21) demonstrated adequate sequence generation and complete outcome data. Due to the nature of the interventions, blinding of clinicians and patients was not feasible, but the incidence of postoperative CR was not considered to be affected. Thus, the aforementioned domains were judged to be at a low risk of bias. On the contrary, the lack of blinding of outcome assessors and the fact that CR, although not pre-specified, was reported as a potential cause of of late postoperative changes after radiographical investigation, indicated high risk of bias. Unclear was the risk of bias regarding the allocation concealment, as no method was described and the other sources bias. Therefore, this study received an overall high risk of bias judgment.

Prospective studies

All the 3 prospective studies (4, 22, 23) were judged to be at a low risk of bias regarding the measurement of interventions and the departures from the intended interventions. They were also found to be at a moderate risk of bias concerning the selection of participants, missing data and the selection of the reported result. Moreover, serious was the risk of bias due to confounding, as no study measured or reported adjustment for all the critically important confounders. Thus, an overall serious risk of bias was considered.

Retrospective studies

The 10 identified retrospective studies (15, 24-32) received a serious overall risk of bias judgment, given the serious risk of bias due to confounding that applied to all. Furthermore, serious was the risk of bias in selection of participants in 5 studies (15, 24, 26, 29, 32), where selection was considered related to both the intervention and the outcome. The presence of co-interventions that were not adjusted for in the analyses in another 5 studies (15, 24, 27, 29, 30) indicated serious risk of bias due to departures from the intended intervention. In addition, in 8 studies (15, 24-29, 32) the outcome measure was considered subjective, the assessors were aware of the received intervention and any error in measuring the outcome was likely related to the intervention status. This raised the risk of bias in measurement of the outcome to a serious level.

3.4 CR following BSSO

In all studies, BSSO was performed for mandibular advancement. It might have also been used for mandibular setback in the study of Wolford et al. (30), who reported surgical Class III correction by mandibular ramus osteotomies, without determining the surgical procedure though.

When BSSO was carried out alone (4, 22, 25, 27, 28, 32) or in conjunction with other surgical procedures (15, 21, 23, 24, 26, 29-31), it resulted in CR, whose incidence ranged from 1.4% (30) to 31% (26). However, the range after a single-jaw BSSO for mandibular advancement (4, 22, 25, 27, 28, 32) was between 3.6% (4) and 10% (28).

Researchers recorded various results trying to quantify CR based on different methods of outcome assessment. More precisely, a vertical decrease of 2 mm or more of the ramus (22, 26, 31) or the condylar height (30) was reported in 4 studies (22, 26, 30, 31). A mean of 4.7 mm of CR with a range between 3 and 8 mm was declared in 1 study (31). A percentage vertical condylar change was stated in 1 study (28). More specifically, from a total of 100 patients, 10 developed CR that ranged between 10-19% in 6, 20-29% in 3 and was greater than 30% in 1 patient. The study of Sceerlinck et al. (25) reported a complete disappearance of the condylar contour in half of the patients that presented CR, while on the other half the condyle was partially resorbed. A 3-dimensional (3-D) quantification of CR was reported in 1 study (4), where CR was greater that 289 mm^3.

Regarding the patient-related factors, a female predominance in CR was pointed out in 4 studies (4, 22, 25, 26). Moreover, patients of a young age (15, 22), with mandibular hypoplasia and a high MPA (4, 15, 22, 24, 26), a posteriorly inclined condylar neck (15, 24, 29) and preoperative TMD were found to be at a greater risk for CR. As for the surgery-related factors, bimaxillary surgery (24) and IMF (28) were strongly correlated with CR in 2 studies (24, 28). The recorded results and conclusions of the included studies are summarised in detail in Table 3.

3.5 Quantitative synthesis of the included studies

Substantial differences in the implemented interventions, participants' characteristics and observational periods among studies were observed. Moreover, an overall high/serious risk of bias judgment was reached for all. Thus, no meta-analysis could be implemented, on the grounds that the existing bias could compound the errors and generate a misleading result that would be interpreted as credible.

DISCUSSION

The incidence of CR following BSSO has already been reported in previous reviews (3, 6-11, 13). However, to date there is no other systematic review investigating the amount of postoperative CR to the knowledge of the authors. Therefore, the present review was carried out in order to systematically assess the current scientific evidence concerning the incidence and quantification of CR following BSSO.

To achieve this one should gain an insight in the causative mechanism first. Although the pathogenesis of CR after orthognathic surgery remains unclear (8, 16), factors that may contribute to the causative mechanism have been identified. Large mandibular advancements are reported to increase the tension of the surrounding soft-tissues producing an inferior-posteriorly directed force (16, 29). This causes compressive loads on the condylar head (33), that may lead to CR if the adaptive capacity of the condyle is exceeded (29). However, the role of the magnitude of mandibular advancement in CR is controversial with some researchers stating increased incidence after excessive mandibular movement (25, 28) and others declaring no direct effect, as the posteriorly directed force does not appear to affect the more susceptible to CR anterior-superior surface of the condyle (16, 34).

Moreover, surgically induced rotational changes are considered critical for CR. Counterclockwise rotation of the proximal mandibular segment induces posterior condylar autorotation that brings the less dense and previously unloaded superior surface of the condylar head more superiorly (35). This renders it susceptible to increased mechanical loads (16, 29). The latter also explains the role of a posteriorly inclined condylar neck on the onset of CR (29, 33). When the condylar neck is inclined posteriorly, the less loaded anterior-superior area of the condyle is more exposed to loading. On the other hand, little is known regarding the effect of the counterclockwise rotation of the distal mandibular segments (16). Finally, restriction of the blood flow in the condyles after surgery is also considered an important factor in the etiology of CR (14, 29, 33).

Although the initial plan was to investigate CR in orthognathic patients requiring BSSO either for mandibular advancement or setback, it was finally assessed only in patients undergoing BSSO for mandibular advancement, as this was reported in all the retrieved studies. Studies with no control groups were decided to be included as well. Albeit these studies would contribute only to the lowest level of scientific evidence, they could still provide valuable clinical information.

Among the retrieved studies, only 1 RCT (21) was identified, most likely due to the inherent limitation and difficulty of randomizing surgical interventions. From the remaining 13 studies, 3 were of prospective (4, 22, 23) and 10 of retrospective design (15, 24-32).

During the examination of the included studies considerable differences with regard to participants' characteristics, types of interventions and observational periods were noted, thus, preventing the implementation of a meta-analysis. More specifically, the number, age, gender distribution, preoperative MPA and existing TMD differed among the treated samples. As for the received intervention, CR following isolated BSSO was investigated in only 6 studies (4, 22, 25, 27, 28, 32). The remaining 8 studies (15, 21, 23, 24, 26, 29-31), reported incidence of CR after bimaxillary surgeries (23, 26, 31) or both isolated BSSO and bimaxillary surgeries in mixed groups of patients (15, 21, 24, 29, 30). Furthermore, implementation of IMF varied among studies. Finally, the observational period ranged among and within studies. As a result, it was difficult to assess the outcomes and reach safe results and conclusions.

In order to alleviate the reported weaknesses and also to increase the strength of the stated results, a strict methodology regarding both data extraction and quality analysis was applied. Only the data that were relative to the incidence and amount of postsurgical CR were recorded in pre-specified forms. Moreover, methodological quality of the studies was based on a risk of bias assessment, as it has already been described.

During the assessment, important parameters were taken into consideration, especially with regard to the non-randomised studies, both prospective and retrospective. Potential confounders and co-interventions that could significantly affect the reported results were determined. Residual confounding was noted in all the non-randomised studies (4, 15, 22-32) and thus a serious risk of bias judgment was justified. A serious risk of bias due to departures from the intended intervention was also considered, when co-interventions, i.e. bimaxillary surgery and IMF, were reported for some, but not all participants of each study and no adjustment for in the analysis was made (15, 24, 27, 29, 30). Nevertheless, moderate was the risk of bias in 2 studies (28, 32), where IMF, in most cases, reflected the natural course of events after initiation of intervention (it was performed routinely in large advancements) (28) or it was not considered critical (32); in Cutbirth et al. (28), IMF was routinely performed in large mandibular advancements (>7mm). Based on ACROBAT-NRSI, regarding the risk of bias due to departures from the indented interventions, a moderate risk of bias is considered when most (but not) all co-interventions (in this case the IMF) reflect the natural course of events after initiation of intervention, thus not critically affecting the results. In the study of Veras et al. (32), IMF was not considered critical for affecting the reported results, as it was performed in only 2 bad-split cases and only for short periods (3 and 7 days). Thus, a moderate risk of bias was considered pertinent for both studies.

With regard to the outcome measure, different methods were implemented among researchers. Most assessors used 2-dimentional (2-D) imaging techniques, such as orthopantomograms (OPGs) (22, 24, 25, 27-29, 32), lateral cephalograms (15, 24-31) and tomograms (30, 31). Although, conventional 2-D images are widely used, the derived measurements of condylar morphology lack accuracy and reproducibility (36, 37). This is, mostly, due to inevitable shortcomings of the images, such as magnification, superimposition of adjacent anatomical structures and linear measurements of 3-D objects that cause considerable interobserver disagreement (36) and complicate the interpretation of results. In contrast, CBCT scans (4, 23) are considered a more objective method, owing to the precise localization and quantification of morphological condylar changes (37,38). Consequently, subjective were considered those results based on OPGs and lateral cephalograms (15, 22, 24-29, 32) while objective those based on CBCTs (4, 23). However, results based on lateral cephalometric TMJ tomograms (30, 31) were regarded as relatively objective, since CR measured as vertical condylar or ramus height shortening can be more accurately assessed relatively to the other 2-D x-rays, but less accurately than a 3-D reconstructed model obtained from CBCT scans.

Overall, evidence was generally of a low quality owing to the perceived high/serious risk of bias in the retrieved studies. The high amount of heterogeneity in terms of methodology and outcome reporting precluded a valid interpretation of the actual results through pooled estimates. There was the substantial consistency among studies, however, that young, female patients with mandibular deficiency and high mandibular plane angle, submitted to surgical counterclockwise rotation of mandibular segments are more prone to a higher risk for CR after BSSO. These observations may, as well, be attributed to preoperative TMDs that affect young adult women to a greater extent and often occur in mandibular retrognathic patients (13, 28, 31). Moreover, it has been reported that small condyles have been radiologically detected in many patients with a high MPA (7, 27). Such condyles may have a less adaptive capacity to increased loading than the shorter and more rounded ones frequently seen in low-MPA individuals. Therefore, following surgery pathologic remodeling may be initiated potentially resulting in condylar resorption.

In the basis of these manifestations, it is evident that more high quality research of prospective design including control samples need to be carried out. Although there are inherent difficulties in performing studies investigating the effects of surgical interventions, as they are dependent on patient needs and standardization of procedures would be unethical, researchers should clearly set their objectives and select their study samples based on specific inclusion criteria. 3-D imaging techniques would also be more valuable for quantifying postoperative alterations of the condylar morphology. At last, reporting on outcomes based on standarised long-term follow-up periods needs better substantiation to allow definitive conclusions.

CONCLUSIONS

The available body of literature confirms the presence of CR as a potential postoperative complication following BSSO. However, the results of the present investigation revealed significant methodological heterogeneity among studies and low level of evidence that preclude definitive conclusions with respect to the incidence and quantification of CR. More high-quality evidence-based clinical trials with proper design and standardized long-term follow-up periods need to be conducted in the future in order to gain more insight into the onset and progression of CR after BSSO. 3-D imaging technology would provide reliable information towards this direction.

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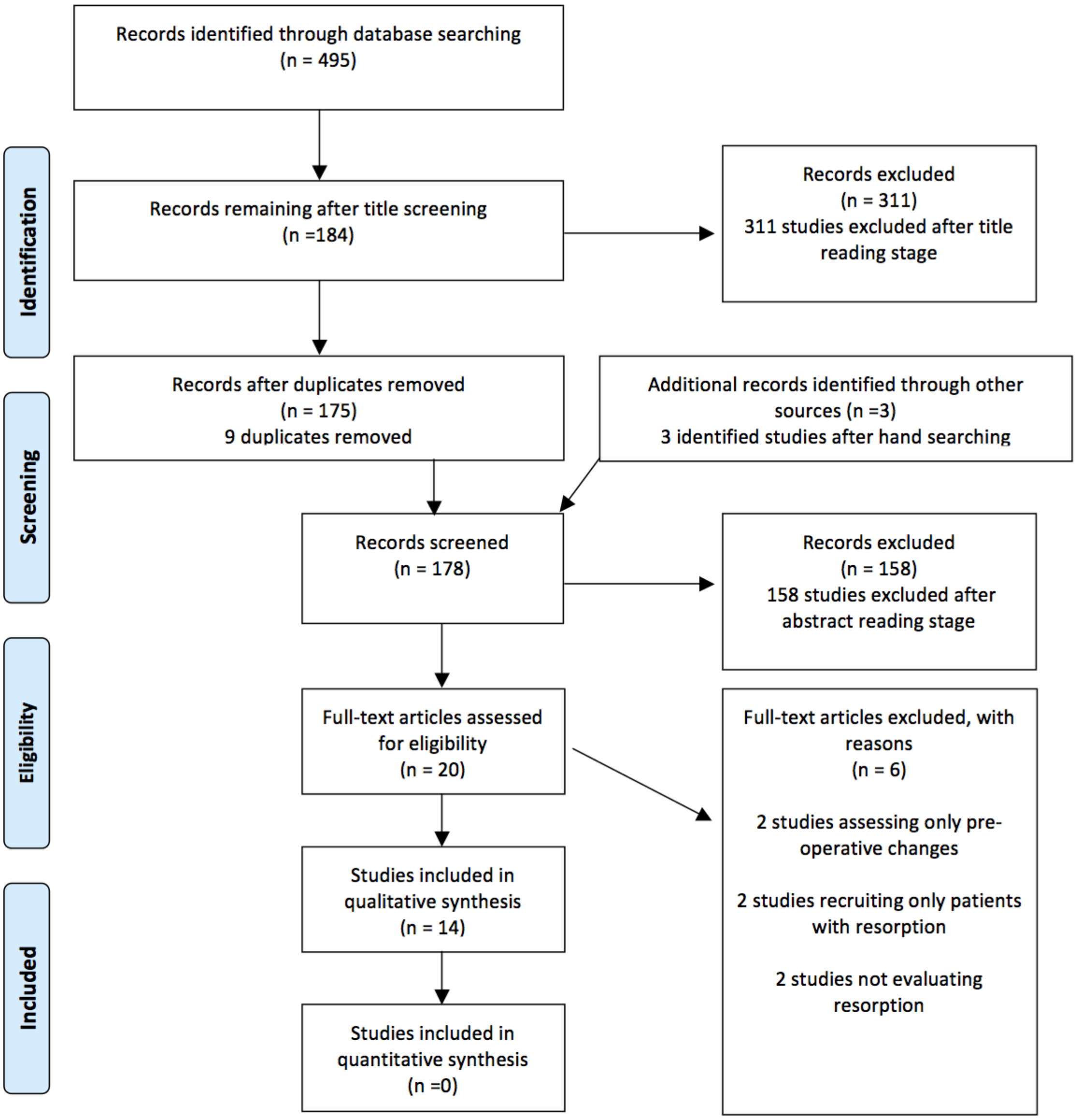
FIGURE LEGEND:

Figure 1: Flow diagram of the study selection process. From Moher D, Liberati A, Tetzla J, Altman D G, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6: e1000097. doi:10.1371/journal.pmed1000097. For more information, visit www. prisma-statement.org (date last accessed, September 26, 2013).



APPENDIX:

Appendix 1. Search strategy -Medline via Pubmed, 29.11.2015.

#1	condylar resorption	281
#2	orthognathic surgery	4008
#3	(condylar resorption) AND orthognathic surgery	40
#4	((condyl*[Title/Abstract]) AND resor*[Title/Abstract]) AND orthognathic[Title/Abstract]	41
#5	(sagittal split osteotom*) AND condyl*[Title/Abstract]	86
#6	(sagittal split osteotom*) AND condyl*[Title/Abstract] AND resorption	17
#7	condylar resorption[MeSH Major Topic]	0
#8	condylar resorption[MeSH Subheading]	0
#9	(mandibular condyles[MeSH Terms]) AND resorption	311
#10	(mandibular condyles[MeSH Terms]) AND resorption[tiab]	199
#11	(mandibular condyles[MeSH Terms]) AND resorption[tiab] AND surgery	140
#12	(mandibular condyles[MeSH Terms]) AND resorption[tiab] AND orthognathic	29
#13	(orthognathic surgery[MeSH Major Topic]) AND condyl*[Title/Abstract]	1
#14	((resorption OR change[Title/Abstract])) AND condyl*[Title/Abstract]	1307
#15	((((resorption OR change[Title/Abstract])) AND condyl*[Title/Abstract])) AND sagittal split osteotom*[Title/Abstract]	29
#16	((((resorption OR change[Title/Abstract])) AND condyl*[Title/Abstract])) AND orthognathic[Title/Abstract]	65

Table 1: Characteristics of the included studies ordered by date.

Author-Year	Title	Study design	Method	Participants	Interventions	Observation period	Outcomes	Method of Outcomes' Assessment
Kerstens et al. (24) - (1990)	"Condylar atrophy and osteoarthrosis after bimaxillary surgery."	retrospective	Single-center study, Setting: Department of Oral and Maxillofacial Surgery of the Free University Hospital, Amsterdam, Year: January 1985-December 1986.	206 patients with dentofacial deformities. Age and gender distribution not reported.	206 patients for surgical correction of dentofacial deformities. 76% treated with BSSO and 43% treated with BSSO + LeFort I osteotomy. IMF in all cases.	Follow-up at least 1 y postoperatively.	Postsurgical condylar atrophy related to the nature of deformity or the surgical technique used.	Pre-and postoperative OPGs, cephalograms, transcranial TMJ radiographs.
Scheerlinck et al. (25) - (1994)	"Sagittal split advancement osteotomies stabilized with miniplates. "	retrospective	Setting: not reported, Year: 1987-9.	103 patients (32M,71F) with mandibular hypoplasia; 32M, mean age: 23.7y (range: 15 - 44.8y) and 71F, mean age: 25.8y (range; 14.1-43,3 y).	All treated with BSSO for mandibular advancement. IMF with tight elastic bands in all cases for 1-3d.	Follow-up: postoperative intervals of 3,6 m, 1 and at least 2 y. (mean: 32m, max: 60m).	CR resulting in relapse after BSSO advancement.	Pre-and postoperative OPGs and cephalometric radiographs.
De Clercq et al. (26) - (1994)	"Condylar resorption in orthognathic surgery: a retrospective study."	retrospective	Single-center study, Setting: Division of Maxillofacial Surgery of the St-Jan Hospital, Brugge, Belgium, Year: January 1987-December 1990.	29 patients (6M,23F) with high-angle mandibular retrognathism, mean age: 23y (range: 15-44y). 23/29 with anterior open bite and 6/29 with deep/normal bite.	All treated with bimaxillary surgery (BBSO for mandibular advancement + LeFort I osteotomy for maxillary replacement).	Follow-up at least 2 y postoperatively.	Postoperative CR resulting in shortening of the ascending ramus.	Cephalograms taken 48h after surgery compared to those taken at least 2y postoperatively.
Bouwman et al. (27) - (1997)	"The value of long-term follow-up of mandibular advancement surgery in patients with a low to normal mandibular plane angle."	retrospective	Single-center study, Setting: Department of Oral and Maxillofacial Surgery at the hospital of the Vrije Universiteit of Amsterdam, The Netherlands, Year: N/A.	*Group A*: 12 mandibular deficient patients (5M,7F) aged 18.3-42.8y (mean: 29.8y) with low to normal MPA: mean 24.7 (range: 20.3 - 30.7); *Group B*: 45 mandibular deficient patients (14M,31F) aged 17.8-50.9y (mean: 28.5y) with low to normal MPA: mean: 26.2 (range: 10 - 32).	Group A: BSSO with IMF; Group B: BSSO without IMF.	Follow up: postoperative intervals of 6 w,1 and at least 5y for group A; at least 1 y for group B.	CR after BSSO mandibular advancement and IMF in patients with a low to normal MPA.	Pre-and postoperative lateral cephalograms for group A; lateral cephalograms and OPGs for group B.
Cutbirth et al. (28) - (1998)	"Condylar Resorption After Bicortical Screw Fixation of Mandibular Advancement."	retrospective	Setting and Year: N/A.	100 patients (30M,70F) aged 13-55y (mean: 27.6y) with mandibular deficiency.	100 BSSO. IMF with elastic traction only in advancements > 7mm.	Follow-up: postoperative radiographic assessment intervals of 6, w, 1 and 5y.	CR after BSSO mandibular advancement. The severity affects long-term stability.	Pre-and postoperative OPGs and cephalometric radiographs. (Cephalometric tracings of radiographs with ≥10% of morphologic condylar changes).
Hwang et al. (29) - (2000a)	"The role of a posteriorly inclined condylar neck in condylar resorption after orthognathic surgery."	retrospective	Setting and Year: N/A.	11 female patients aged 16-28y (mean: 19y) with mandibular hypoplasia. 8/11 with anterior open bite.	10 patients had BSSO + LeFort I osteotomy; 1 had isolated BSSO. IMF in 5/11 for 4w.	Follow-up: until 2y postsurgically.	Postoperative CR in patients with a posteriorly inclined condylar neck in connection with the surgical mandibular movement.	Pre-and postoperative OPGs and cephalometric radiographs.
Wolford et al. (30) - (2002)	"Concomitant Temporomandibular Joint and Orthognathic Surgery: A Preliminary Report."	retrospective	Setting: not reported, Year: from 1991 through 1993.	70 patients with preoperative TMJ dysfunction symptoms: *Group I*: 51 Class II patients divided in: *Ia*: 40 patients (2M,38F) mean age: 30.9y (range: 14-61y), *Ib*: 11 patients (1M,10F) mean age: 28.6y (range: 18-54y); *Group II*: 7 Class III patients (2M,5F)	*Group I* had: *Ia*: 40 bimaxillary osteotomies + TMJ disc repositioning and *Ib*: 11 isolated mro for mandibular advancement+ TMJ disc repositioning; *Group II* had TMJ disc repositioning and mro for mandibular setback; *Group III* had	Follow-up: postoperative intervals of 6,12 m and the longest possible (average: 27.7m, range: 12-101m)	CR after orthognathic surgery with concomitant TMJ disc repositioning.	Pre-and postoperative lateral cephalometric radiographs and tomographs.

				mean age: 22.3y (range: 13-45y); *Group III*: 12 Class I patients (6M,6F) mean age: 28.7y (range: 13-61y).	TMJ disc repositioning mro only for occlusal control.			
Wolford et al. (31) - (2003)	"Changes in Temporomandibular Joint Dysfunction After Orthognathic Surgery."	retrospective	Single-center study, Setting: single private practice, Year: from 1991 through 1996.	25 patients (2M,23F) aged 12-49y (mean:24y) with dentofacial deformities and preexisting TMJ internal derangement.	25 maxillary osteotomies+BSSOs; 24/25 for mandibular advancement of 9 mm on average.	Follow-up: 2.2y on average (range: 12m-81m) postsurgically.	Postoperative CR resulting in the development of Class II open bite malocclusion.	Pre-and postoperative lateral cephalograms and lateral cephalometric TMJ tomograms.
Hwang et al. (15) - (2004)	"Non-surgical risk factors for condylar resorption after orthognathic surgery."	retrospective	Setting and Year: N/A.	*Group I*: 17 Class II mandibular hypoplasia females, mean age: 19.8±3.8 y with postoperative CR; *Group II*: 22 mandibular hypoplastic patients (3M,19F) mean age: 25.4±8.5 y with preoperative MPA>40 and no postoperative CR.	*Group I*: BSSO+LeFort I osteotomies in16/17, while isolated BSSO in 1/17. IMF in 9/17 for 4w; *Group II*: 18 bimaxillary, 2 isolated BSSO and 2 LeFort I osteotomies. IMF in 6/22 for 4w.	Follow-up: postoperative intervals of 6 w,1 and 2 y.	Non-surgical risk factors for CR after orthognathic surgery.	Pre-and postoperative OPGs and postoperative lateral cephalometric radiographs.
Borstlap et al. (22) - (2004)	"Stabilization of sagittal split advancement osteotomies with miniplates: a prospective, multicentre study with two-year follow-up Part III—Condylar remodeling and resorption."	prospective	Multi-center study. Setting and Year: N/A.	222 patients (53M,169F), mean age: 25y (range: 13-53y).	222 patients treated with BSSO for mandibular advancement.	Follow-up: postoperative intervals of 3,6 and 24 m.	CR after BSSO for mandibular advancement in relation to postoperative relapse.	Pre-and postoperative CMS on OPGs.
Veras et al. (32) - (2008)	"Functional and radiographic long-term results after bad split in orthognathic surgery."	retrospective	Setting and Year: N/A.	110 mandibular hypoplasia patients divided in 2 matched groups; *Group A*: 7 patients (3M,4F), mean age: 32.4y (range: 25-43) *Group B*: 7 patients (3M,4F), mean age: 24.4y (range:22-38).	Both groups underwent single-jaw BSSO. *Group A*: 7 BSSO with subsequent bad split; *Group B*: 7 BSSO with normal split. IMF in only 2 patients (Group A) for 3 and 7d.	Follow-up: at least 6 m (mean: 28.6 m).	Evaluation of condylar morphology and ramus height between two groups.	Pre-and postoperative CMS on OPGs.
Ow and Cheung (21) - (2010)	"Bilateral sagittal split osteotomies versus mandibular distraction osteogenesis: a prospective clinical trial comparing inferior alveolar nerve function and complications."	RCT	Setting and Year: N/A.	23 Class II mandibular hypoplasia patients randomly assigned to 2 groups: *BSSO group*: 12 patients (3M,9F), mean age: 26.5y (no SD given); *MDO group*: 11 patients (2M,9F), mean age: 25.3y (no SD given).	12 had BSSO; 11 had MDO. *In the BSSO group*: 3 single+9 double jaw surgeries; *in the MDO group*: 2 single+9 double jaw surgeries.	Follow-up: postoperative intervals of 2,6,12 w and 6,12 m.	CR in the late postoperative period after both surgical techniques.	Pre-and postoperative radiographic examination and cephalometric analysis (not specified).
Chen et al. (23) - (2015)	"Three- dimensional evaluation of condylar morphology remodeling after orthognathic surgery in mandibular retrognathism by cone-beam computed tomography." (article in Chinese.)	prospective	Setting: Department of Oral and Maxillofacial Surgery, Peking University School and Hospital of Stomatology, Beijing, China. Year: N/A.	18 patients (5M,13F) requiring mandibular advancement therapy, mean age: 25.5±4.5 y.	18 bimaxillary surgeries (Le Fort I + BSSRO).	Follow-up: 12 m postsurgically.	Evaluation of condylar morphology changes after orthognathic surgery.	3D condylar surface reconstruction using CBCT.
Xi et al. (4) - (2015)	"3D analysis of condylar remodeling and skeletal relapse following bilateral sagittal split advancement osteotomies."	prospective	Setting: Department of Oral and Maxillofacial Surgery in Radboud University Nijmegen Medical Centre. Year: between 2007 and 2011.	56 patients (17M,39F) with mandibular hypoplasia, mean age: 30.2±12.5y (range: 15-54); low-angle group: 28 patients (MPA=27.9°±3.18°), high-angle group: 28 patients (MPA= 38.7°±5.64°).	All 56 patients were treated with BSSO for mandibular advancement.	Follow-up: postoperative intervals of 1w and 1y.	Quantification of postsurgical condylar volume alterations and investigation of their role in skeletal stability after BSSO advancement surgery.	CBCT scan (3D-cephalometry and condylar volume analysis).

BSSO: bilateral sagittal split osteotomy, IMF: intermaxillary fixation, y: years, m: months, w: weeks, d: days, h: hours, OPGs: orthopantomograms, TMJ: temporomandibular joint, M: male, F: female, CR: condylar resorption, N/A: Not available, MPA: mandibular plane angle, mro: mandibular ramus osteotomy, CMS: condylar morphology scale, MDO: mandibular distraction osteogenesis, BSSRO: bilateral sagittal split ramus osteotomy, 3D: three-dimensional, CBCT: cone-beam computed tomography.

Table 2: Risk of bias assessment ordered by date.

Author-Year	Study design	Sequence generation (selection bias)	Allocation Concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessors (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other sources of bias
Ow and Cheung (21) - (2010)	**RCT**	**Aj: Low Risk** **Sfj:** "Computer generated randomization table"	**Aj: Unclear Risk** **Sfj:** Method not described	**Aj: Low Risk** **Sfj:** No blinding of participants, but CR is not likely to be influenced by lack of blinding.	**Aj: High Risk** **Sfj:** No blinding of outcome assessors that might have influenced the outcome.	**Aj: Low Risk** **Sfj:** No missing outcome data.	**Aj: High Risk** **Sfj:** CR, although not pre-specified, was reported after radiographical investigation of late postoperative changes in both groups.	**Aj: Unclear Risk** **Sfj:** 1) small number of participants, 2) more female patients in both groups without reporting the effect of gender in outcomes/outcomes measures.
Author-Year	**Study design**	**Bias due to confounding (selection bias)**	**Bias in selection of participants (selection bias)**	**Bias in measurement of interventions (misclassification-, information-, recall-, measurement-, observer bias)**	**Bias due to departures from intended interventions (performance bias)**	**Bias due to missing data (attrition-, selection bias)**	**Bias in measurement of outcomes (detection-, recall-, information-, misclassifiction -, observer-, measurement bias)**	**Bias in selection of the reported result (outcome reporting-, analysis reporting bias)**
Kerstens et al. (24) - (1990)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Serious Risk** **Sfj:** Selection was related to intervention and likely to the outcome.	**Aj: Moderate Risk** **Sfj:** Intervention status is well-defined, but data were obtained retrospectively in aa way that could have been affected by knowledge of the outcome.	**Aj: Serious Risk** **Sfj:** Co-intervention is apparent and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on age-gender) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Scheerlinck et al. (25) - (1994)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Although selection was unrelated to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Low Risk** **Sfj:** No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
De Clercq et al. (26) - (1994)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Serious Risk** **Sfj:** Selection was related to intervention and likely to the outcome.	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time	**Aj: Low Risk** **Sfj:** No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/

				of intervention.		across interventions and missing data were not addressed in the analysis.	assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Bouwman et al. (27) - (1997)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Although selection was related to intervention and probably not to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Moderate Risk** **Sfj:** Intervention status is well-defined, but data were obtained retrospectively in a way that could have been affected by knowledge of the outcome.	**Aj: Serious Risk** **Sfj:** Co-intervention is apparent and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Cutbirth et al. (28) - (1998)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Although selection was related to intervention and probably not to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Moderate Risk** **Sfj:** Intervention status is well-defined, but some assignments of intervention status (i.e. the number of patients that had IMF) were determined retrospectively in a way that could have been affected by knowledge of the outcome.	**Aj: Moderate Risk** **Sfj:** Most (but not all) departures from the intended intervention (patients that had IMF) reflect the natural course of events after initiation of intervention (routinely performed IMF in large (>7mm) advancements)	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Hwang et al. (29) - (2000a)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Serious Risk** **Sfj:** Selection was related to intervention and to the outcome.	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Serious Risk** **Sfj:** Co-interventions are apparent and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Wolford et al.	**r-NRS**	**Aj: Serious Risk**	**Aj: Low Risk**	**Aj: Low Risk**	**Aj: Serious Risk**	**Aj: Moderate**	**Aj: Moderate**	**Aj: Moderate**

(30) - (2002)		**Sfj**: Critically important confounders not measured and not adjusted for in the analysis.	**Sfj**: All participants who could have been eligible for the target trial were included in the study and start f follow up and start of intervention coincide for all subjects.	**Sfj**: Intervention status is well-defined and based solely on information collected at the time of intervention.	**Sfj**: Co-intervention is apparent and not adjusted for in the analysis.	**Risk** **Sfj**: Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Risk** **Sfj**: The outcome measure was relatively objective (lateral cephalometric tomograms), but the assessors were aware of the received intervention and any error in measuring the outcome could have been related to intervention status.	**Risk** **Sfj**: Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Wolford et al. (31) - (2003)	**r-NRS**	**Aj: Serious Risk** **Sfj**: Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj**: Although selection was unrelated to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Low Risk** **Sfj**: Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Low Risk** **Sfj**: No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj**: Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Moderate Risk** **Sfj**: The outcome measure was relatively objective (lateral cephalometric tomograms) and outcome measure was unlikely to have been influenced by knowledge of intervention. However, any error in measuring the outcome is likely to be related to	**Aj: Moderate Risk** **Sfj**: Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different
							confounders.	subgroups.
Hwang et al. (15) - (2004)	**r-NRS**	**Aj: Serious Risk** **Sfj**: Critically important confounders not adjusted for in the analysis.	**Aj: Serious Risk** **Sfj**: Selection was related to both the intervention and the outcome.	**Aj: Low Risk** **Sfj**: Intervention status is well-defined and based solely on information collected at the time of intervention (No bias due to misclassification of interventions is expected).	**Aj: Serious Risk** **Sfj**: Co-interventions are apparent and not adjusted for in the analysis.	**Aj: Low Risk** **Sfj**: Data were reasonably complete.	**Aj: Serious Risk** **Sfj**: Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj**: Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Borstlap et al. (22) - (2004)	**p-NRS**	**Aj: Serious Risk** **Sfj**: Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj**: Although selection was unrelated to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Low Risk** **Sfj**: Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Low Risk** **Sfj**: No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj**: Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Serious Risk** **Sfj**: Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Moderate Risk** **Sfj**: Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-

								outcome relationship or different subgroups.
Veras et al. (32) - (2008)	**r-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Serious Risk** **Sfj:** Selection was related to intervention and to a possible cause of the outcome (bad-split).	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Moderate Risk** **Sfj:** Although IMF is present, it is not considered to significantly impact the intended treatment effect or the outcome (only in 2 cases- no significantly different results between the 2 groups- only remodeling of the condyles)	**Aj: Serious Risk** **Sfj:** The nature of the missing data (data on condylar morphology for every patient to clarify the incidence of CR) means that the risk of bias cannot be removed through appropriate analysis (statistical analysis of only the average values that show remodeling of condylar morphology)	**Aj: Serious Risk** **Sfj:** Outcome measure was subjective, probably assessed by outcome assessors aware of the received intervention and any error in measuring the outcome was related to intervention status.	**Aj: Serious Risk** **Sfj:** There is a high risk of selective reporting from among multiple analyses.
Chen et al. (23) - (2015)	**p-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Although selection was probably unrelated to the outcome, the study can't be considered comparable to a well- performed RCT, since there was no control group.	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Low Risk** **Sfj:** No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Moderate Risk** **Sfj:** The outcome measure was objective (CBCTs). However, outcome measure could have been minimally affected by knowledge of the intervention and any error in measuring the outcome was minimally related to intervention status (without significantly affecting the outcome).	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.
Xi et al. (4) - (2015)	**p-NRS**	**Aj: Serious Risk** **Sfj:** Critically important confounders not measured and not adjusted for in the analysis.	**Aj: Moderate Risk** **Sfj:** Although selection was probably unrelated to the outcome (prospective), the study can't be considered comparable to a well-performed RCT, since there was no control group.	**Aj: Low Risk** **Sfj:** Intervention status is well-defined and based solely on information collected at the time of intervention.	**Aj: Low Risk** **Sfj:** No bias due to departures from the intended intervention is expected.	**Aj: Moderate Risk** **Sfj:** Reasons for missingness (data on confounders) differ minimally across interventions and missing data were not addressed in the analysis.	**Aj: Low Risk** **Sfj:** The outcome measure was objective (CBCTs), knowledge of the intervention was not likely to affect the outcome measure and any error in measuring the outcome was likely unrelated to intervention status.	**Aj: Moderate Risk** **Sfj:** Outcome measurement and analyses were consistent with an a priori plan/ clearly defined and there was no indication of selective reporting of the declared effect estimate from multiple analyses of the intervention-outcome relationship or different subgroups.

RCT indicates Randomized Clinical Trial, r-NRS: retrospective-Non Randomized Study, p-NRS: prospective-Non Randomized Study, Aj: Authors' judgment, Sfj: Support for judgment.

Table 3: Results and Conclusions of the included studies ordered by date.

Author - Year	Title	Results	Conclusions
Kerstens et al. (24) - (1990)	"Condylar atrophy and osteoarthrosis after bimaxillary surgery"	12 patients with condylar atrophy 1 y postoperatively (3 with bilateral and 9 with unilateral bone loss). All presented high-angle mandibular retrognathia (Class II open bite) and all but 1 had bimaxillary surgery. In 87% more posteriorly located condyle. The greatest amount of bone loss was in the anterior condylar surface, although not quantified. 3/12 with preoperative osteoarthritic changes.	Condylar atrophy is related to the surgical treatment of high-angle mandibular deficiency. Increased loading, disc displacement due to rotation/autorotation and immobilization in orthognathic surgery act as aggravating factors. The role of age and gender distribution were not investigated.
Scheerlinck et al. (25) - (1994)	"Sagittal split advancement osteotomies stabilized with miniplates"	8 patients (1M,7F) with CR (7.7%) resulting in considerable decrease of ramus height; 6/8 with unilateral and 2/8 with bilateral CR. 4/8 with complete disappearance of the condylar contour, while 4/8 with the condyle partially resorbed. 7/8 with preexisting signs of TMJ dysfunction. 20 times higher risk of PCR for advancements >10mm compared to ≤ 5mm.	Stabilization with miniplates after BSSO leads to predictable and stable results, although 7,7% of the patients seem to undergo PCR. A greater amount of mandibular advancement in mm increases the risk more frequently in females at 3-33%.
De Clercq et al. (26) - (1994)	"Condylar resorption in orthognathic surgery: a retrospective study"	In 9/29 (31%), all females, the ramus' resorption>2 mm or >6% of the total ramal length. No correlation between CR and age, amount of retrognathism or preoperative symptoms of TMJ dysfunction.	Females with high-angle mandibular retrognathism + anterior open bite run a high risk of developing CR in 6m-2y postoperatively. No statistically significant outcomes regarding the degree of retrognathism, age and preexisting TMJ dysfunction.
Bouwman et al. (27) - (1997)	"The value of long-term follow-up of mandibular advancement surgery in patients with a low to normal mandibular plane angle"	Group A: 1/12 (19 years old-female) showed CR in the first postsurgical year. No evidence about the amount of CR or the presence of preoperative TMJ dysfunction. Group B: 0/45 showed CR.	Relapse due to incidence of CR is not likely to occur after BSSO for mandibular advancement in retrognathic patients with a low to normal MPA. Reliable results given the clinically insignificant long-term changes.
Cutbirth et al. (28) - (1998)	"Condylar Resorption After Bicortical Screw Fixation of Mandibular Advancement"	10/100 patients (2M,8F) with ≥10% vertical condylar change. All unilateral. (6/10 had 10-19% CR, 3/10 had 20-29% CR and 1/10 had CR>30%). 8/10 with preoperative TMJ symptoms. For those with CR mean mandibular advancement: 7.75±2.1mm at B point, while 6.38±1.7 mm for those without CR. IMF in only 6/10 with CR.	Large amount of advancement and preoperative TMJ symptoms are associated with an increased risk of CR. No significant differences in CR regarding the sex, age, MPA and IMF.
Hwang et al. (29) - (2000a)	"The role of a posteriorly inclined condylar neck in condylar resorption after orthognathic surgery"	All had posteriorly inclined condylar neck. 1/11 with unilateral and 10/11 with bilateral CR. 8/11 with symmetrical and 3/11 with asymmetric CR. In 10/11 CR still 2y postoperatively. Average mandibular advancement: 9.1 mm, average counterclockwise rotation of proximal segments: 6.7° for all. No evidence regarding the role of age and gender in CR.	Patients with a posteriorly inclined condylar neck who undergo surgical mandibular movement, especially rotation of the condyle, run a high risk of developing CR.
Wolford et al. (30) - (2002)	"Concomitant Temporomandibular Joint and Orthognathic Surgery: A Preliminary Report"	1 patient from group I (age, gender not reported) with an average surgical change of 7.7 mm (range: 2-22) showed significant postsurgical CR with loss of vertical condylar height (2 mm).	CR may occur after mandibular advancement surgery in the presence of TMJ disc displacement. Early surgical intervention suggested due to significant decrease of success rate when pre-existing TMJ dysfunction lasts > 48m.
Wolford et al. (31) - (2003)	"Changes in Temporomandibular Joint Dysfunction After Orthognathic Surgery"	6/25 patients (24%) had significant condylar resorption of 4.7 mm (range: 3-8 mm) with skeletal and occlusal instability resulting in a Class II anterior open bite malocclusion. Age and gender not reported.	CR may occur in patients with displaced articular discs undergoing mandibular advancements with counterclockwise rotation.
Hwang et al. (15) - (2004)	"Non-surgical risk factors for condylar resorption after orthognathic surgery"	Group I significantly younger than Group II. Preoperative symptoms of TMJ dysfunction in both groups. Significantly greater posterior inclination of the condylar neck in Group I. Preoperative MPA in Group I (mean: 49.41°) significantly greater than in Group II (mean: 44.91°). Significantly smaller preoperative SNB angle, overbite, and TPFH/TAFH in Group I. No significant difference in gender between the two groups.	A significant increased risk of CR was associated with younger patients with mandibular hypoplasia, decreased posterior facial height, overbite, increased MPA and posterior inclination of the condylar neck.
Borstlap et al. (22) - (2004)	"Stabilization of sagittal split advancement osteotomies with miniplates: a prospective, multicentre study with two-year follow-up Part III—Condylar remodeling and resorption"	8/222 (4%) females with CR postsurgically (5 unilaterally and 3 bilaterally affected). Clinical relapse significantly higher in the resorption group. No significant differences in terms of gender distribution. Statistically significant correlation between CR and a steep MPA, the TPFH/TAFH ratio and the surgical mandibular advancement (to a certain extent).	Young patients (<14 y) have a higher risk for CR. A steep MPA and the facial height ratio are significantly related to CR, although MVRA showed their limited value. Pain and TMJ symptoms at the first few months postoperatively are highly suspicious for future condylar changes.
Veras et al. (32) - (2008)	"Functional and radiographic long-term results after bad split in orthognathic surgery"	Not statistically significant alterations of condylar morphology and ramus height within groups, through CMS. No statistical significance in age, gender and postoperative TMJ dysfunction signs and symptoms.	Condylar head after BSSO showed only remodeling, which did not significantly affect the ramus height.
Ow and Cheung (21) - (2010)	"Bilateral sagittal split osteotomies versus mandibular distraction osteogenesis: a prospective clinical trial	CR in 1 BSSO and 1 MDO patient. No significant differences regarding the age and the amount of mandibular advancement between the 2 groups. Role of gender and preoperative TMJ dysfunction symptoms not investigated.	Despite its low incidence, CR was reported in both groups and both may share common risk factors for its postsurgical development.

	comparing inferior alveolar nerve function and complications"		
Chen et al. (23) - (2015)	"Three-dimensional evaluation of condylar morphology remodeling after orthognathic surgery in mandibular retrognathism by cone-beam computed tomography." (article in Chinese.)	The difference in the condylar head dimensions before- and 1 y after surgery was 0.37±0.11mm, which was statistically significant ($p<0.005$). Bone remodeling in different areas was statistically significant ($P<0.05$). Bone resorption occurred mainly in the posterior area of condylar head, while bone formation occurred mainly in the anterior area.	3D-superimposition method based on CBCTs showed remodeling of condylar morphology after mandibular advancement surgery.
Xi et al. (4) - (2015)	"3D analysis of condylar remodeling and skeletal relapse following bilateral sagittal split advancement osteotomies"	PCR (CR>17% of the original condylar volume) occurred in 3.6% of the total. Patients with PCR were included in the CR_{2SD} group where CR> 289mm^3. They were all from the high-angle group. Significant relapse both in the horizontal and the vertical direction, significant decrease in posterior facial height ($S\text{-}Go_{mean}$) and increase in MPA. Significantly more CR and relapse at Pogonion and MPA in females postsurgically.	Postsurgical skeletal relapse and condylar volume decrease are interrelated and both found significantly greater in females with a high-MPA. Gender, presurgical condylar volume and downward surgical displacement of Pogonion are predisposing factors for CR.

M: male, F: female, CR: condylar resorption, PCR: progressive condylar resorption, BSSO: bilateral sagittal split osteotomy, y: years, m: months, w: weeks, d: days, MPA: mandibular plane angle, IMF: intermaxillary fixation, TPFH/TAFH: total posterior facial height versus total anterior facial height, MVRA: multi variance regression analysis, CMS: condylar morphology scale, MDO: mandibular distraction osteogenesis, 3D: three-dimensional.